Special Issue: Current LCA-ISO Activities

Goal and Scope Definition and Life Cycle Inventory Analysis

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1 Introduction

The first applications of ecobalancing began about 20 years ago. At that time, initiated through the oil crisis, energy represented the primary aspect of ecobalancing. This was subsequently followed closely by such further categories as those dealing with resource consumption, emissions and wastes. According to the present definition, such investigations would today be considered as Life Cycle Inventory Analysis. An expansion of this instrument followed consequently through the inclusion of the stages of impact assessment and improvement (today called interpretation) to form the Life Cycle Assessment (LCA).

In the past (until about 1993), international discussions on the development of ecobalancing were primarily kept active through the "Society for Environmental Toxicology and Chemistry" (SETAC). Workshops on various topics incorporating approximately 50 scientists each and symposiums involving a discussion of the results obtained in the workshops were the most important actions. The results of these organisations have been published in the form of a book. Especially important for the topics handled here are:

- A Technical Framework for Life-Cycle Assessment; Vermont, USA, August 1990
- Life-Cycle Assessment: Inventory, Classification, Valuation, Data Bases; Leiden, The Netherlands, December 1991
- Data Quality; Wintergreen, USA, October 1992
- Code-of-Practice; Sesimbra, Portugal, April 1993

The **Technical Committee 207** which has since been occupied with standardisations taking place in the environmental fields was founded by the "International Standard Organization" (ISO) in May 1993 to complement the activities of the SETAC. This action was based on the groundwork performed by the SAGE (Strategic Advisory Group on Environment) and on the suggestions made by the **Business Council for Sustainable Development**. The working fields of this Committee include the topics:

- environmental management
- environmental auditing
- environmental performance evaluation
- environmental labelling.

A subcommittee (subcommittee 5; SC 5) to Technical committee 207 is concerned with **ecobalancing**. With a meeting in November 1993, SC 5 took up its work. The chairman of this group comes from Germany (Dr. Manfred MARSMANN, Bayer AG), the secretarial official comes from France (François POUPET, AFNOR).

Five working groups (Wgs) have been formed in the SC 5 to carry out the standardisation functions as outlined in the steps for the performance of an LCA by SETAC. The topics discussed here are handled by **WG 2** (Life Cycle Inventory Analysis – In General) and **WG 3** (Life Cycle Inventory Analysis – Specific).

The author is in charge of **WG 2**, while **WG 3** has been guided by Prof. Hisashi ISHITANI, Japan, and, since the end of 1995, by Kouji MATSUDA, Japan.

Frank CONSOLI (USA) is in charge of **WG 1** (Life Cycle Assessment – General Principles and Procedures), Sven Olof RYDING (Sweden) is the chairman of **WG 4** (Life Cycle Impact Assessment) and Henri LECOULS the chairman of **WG 5** (Life Cycle Assessment Interpretation).

2 Work Performed by WG 2 & 3

In close co-operation with SC 5, WG 2 & 3 have performed the defined functions. For ISO document 14040, the design of a **Goal and Scope Definition** (GSD) as well as a **Life Cycle Inventory** was initially organised. This was followed subsequently by the work of **ISO 14041** which provided a more detailed description (i.e. **how?**) of those processes contained in ISO 14040 (i.e. **what?**).

ISO CD 14041 deals with two phases of LCA, the **Goal and Scope (GSD)** as well as the **Life Cycle Inventory Analysis (LCI)**, as defined in ISO/DIS 14040.

"**ISO CD 14041** is concerned with special requirements and the procedures dealing with

- formulating the goal and scope of the study
- defining and modelling the systems to be analysed, including data quality considerations
- collecting the data
- verifying and evaluating the reliability of the results of the LCI study
- interpreting the results of an LCI
- reporting the results of an LCI."

To date, the WGs have called together eight meetings in order to carry out these functions. According to the official lists, 49 experts from 17 different countries have been involved. Observers from other countries have also taken part in each of these meetings.

3 Structure of ISO CD 14041

Following a general introduction and an explanation of definitions, ISO CD 14041 contains a section titled "Technical Introduction" in which the standarisation field is explained in detail. **Product systems, Unit processes, Data categories** and **Modelling product systems** are covered in the subsections.

Section 5 deals with the **Goal and Scope Definition**, the first phase of an LCA. It is subdivided into the two sections "Goal of the study" and "Scope of the study". The latter is subdivided further and contains sections on the "Function and functional unit", "Definition of the initial system boundaries", "Data categories", "**Criteria for initial inclusion of inputs and outputs**", "**Data quality requirements**" and a "Critical review". The underscored sections will be discussed in detail in the following.

Section 6 deals with Inventory analysis, the second phase of an LCA. This section is subdivided into sections on "Preparing for data collection", "Data collection", "Calculation procedures" (with subsections concerning "Validation of data", "Relating data to the unit process", "Relating data to functional unit and data aggregation", "Refining the system boundaries"), "Allocation and recycling" (with subsections involving "**Allocation principles**", "**Allocation procedure**", "Recycling").

Section 7, "Defining the limitation of LCI study", provides a description of some of the details which have to be taken into consideration for these processes.

Section 8 provides an explanation of "Reporting".

Appendix: Examples of data collection sheets, Examples of different allocation procedures as well as **Examples for recycling** are to be found in the informative Appendix.

4 Goal and Scope Definition (GSD)

The importance of this **first phase of an LCA study** is occasionally underestimated. Such underestimation, however, routinely involves substantially more work in performing the study, especially in cases where the data collected proves to be insufficient for fulfilling the goal of the study and the data must consequently be collected anew. This can be avoided by planning carefully during the GSD phase.

As already described, section 5 of ISO CD 14041 contains details concerning this phase. A special problem in the compilation of this section involved the transverse relationships between the work of **WG 4** (Impact Assessment) and **WG 5** (Interpretation) since the GDS phase must apply to the entire LCA and not only to the inventory phase. Since the requirements of this working group have not yet been defined in detail, and because of the complex theme, descriptions to date are still limited to only a general presentation. Should it be necessary, this section will undergo a revision.

4.1 Criteria for initial inclusion of inputs and outputs

Since the investigation of a complete system is theoretically and practically impossible, the limitations of the system being studied must be defined at the start of such an LCA study. The definition of these limitations must occur on the basis of clear and comprehensible criteria. For this purpose, the working group worked out the following suggestions:

"There are several criteria that are used in LCA practice to decide which inputs will be studied, including 1) **mass**, 2) **energy** and 3) **environmental relevance**. Making the initial identification of inputs based on mass contribution alone may result in important inputs being omitted from the study. Accordingly, energy and environmental relevance may also be used as criteria in this process."

- "**Mass**: An appropriate decision rule, when using mass as a criteria, would be to require the inclusion in the study of all inputs that cumulatively contribute more than a defined percentage to the mass input of the product system being modelled. The remaining inputs may, as an initial matter, be excluded from the study."
- "**Energy**: Similarly, a criterion may be established to require the inclusion in the study of those inputs that cumulatively contribute a defined percentage of the product system energy inputs."
- "**Environmental relevance**: Decision rules for environmental relevance criteria could be established to include inputs that contribute more than an additional defined percentage to each identified environmental input of the product system. For example, if sulfur oxides were selected as a data category, a criterion could be established to include any inputs that contribute more than an additional defined percentage to the total sulfur oxide emissions for the product system."

"These criteria can also be used to identify which outputs should be traced to nature, i.e. by including final waste treatment processes."

4.2 Data quality requirements

Depending on the goals of the study, the data applied must sufficiently fulfill specific quality requirements. These requirements must already be defined before beginning with the data collection. During and after the collection of data, investigations must be undertaken to see whether or not the available data fulfills these requirements (see Data collection, Calculation procedures).

"Initial data requirements shall be established which define the following parameters":
"**Time-related coverage**: The desired age (e.g. within the last five years and the minimum length of time (e.g. annually)."

"**Geographical coverage**: Geographic area from which data for unit processes should be collected to satisfy the goal of the study (e.g. local, regional, national, continental, global)."

"**Technological coverage**: Nature of the technology mix (e.g. weighted average of the actual process mix, best available technology or worst operating unit)."

"Further descriptions which define the nature of the data such as data collected from specific sites *vs* data from published sources, and whether the data should be measured, calculated or estimated shall also be considered."

"Data from specific sites should be used for those processes that contribute the majority of the mass and energy flows in the systems being studied as determined in the sensitivity analysis performed in section 5.2.3.

Data from specific sites should also be used for unit processes that are considered to have environmentally relevant emissions."

"In all studies, the following additional quality indicators shall be taken into consideration at a level of detail dependent on the goal and scope definition":

"**Precision**: Measurement of the variability of the data values for each data category expressed (e.g. variance)."

"**Completeness**: Percentage of locations reporting primary data from the potential number existing for each data category in a unit process."

"**Representativeness**: Qualitative assessment of degree to which the data set reflects the true population of interest (i.e. geographic and time period, and technology coverage)."

"**Consistency**: Qualitative assessment of how uniform the study methodology is applied to the various components of the analysis."

"**Reproducibility**: Qualitative assessment of the extent to which information about the methodology and data values allow an independent practitioner to reproduce the results reported in the study."

5 Life Cycle Inventory Analysis

The **second phase of an LCA** deals primarily with the collection and processing of data. Data collection continues to represent the step in most studies requiring the most intensive work and is therefore also the most expensive measure, a feature which consequently necessitates especially careful planning. In this field, however, **ISC CD 14041** can only provide general requirements since the details are highly dependent on the specific context.

Numerous computer programs are available for the handling of data. A standardisation of the formats with the goal of compatibility appears to be mandatory and must also be taken into consideration in the future standardisation processes.

A central, methodical problem within the phase of Inventory Analysis involves the field of Allocation which is covered below.

5.1 Allocation

Problems of allocation frequently arise in LCA studies. Two products, for example, can be manufactured in a unit process. One product is used within the system while the other product is leaving the system. **How** must the burdens (e.g. resource consumption or emissions) be divided between the two products?

Another example is seen in the waste treatment process. Various inputs in this process are handled, although only one input comes from the system being examined. Once again, the question is **how** to divide the burdens.

The working group has developed several principles which can be applied in general:

"Since the inventory is intrinsically based on material balances between inputs and outputs, allocation procedures should approximate such fundamental input-output relationships and characteristics as much as possible. Some principles should be kept in mind when allocating loadings. They are general and thorough enough to be applicable to co-products, internal energy allocation, services (e.g. transport, waste treatment), and to either open or closed-loop recycling."

- "The product system under consideration seldom exists in isolation; it generally includes unit processes which may be shared with other product systems. The study should identify these unit processes and deal with them according to the procedures presented below."
- "The inputs and outputs of the unallocated system should equal the sum of the corresponding inputs and outputs of the allocated system. Any deviation from mass and energy balance shall be reported and taken into consideration."
- "Whenever several alternative allocation procedures seem applicable, a sensitivity analysis shall be conducted to illustrate the consequences of the departure from the selected approach."

Based upon these principles, hierarchically ordered allocation procedures are suggested. Strictly speaking, the first procedure is not an allocation process, but represents instead a possibility of avoiding an eventual allocation problem.

"1) Whenever possible, allocation should be avoided or minimised. This may be achieved by sub-dividing the unit process into two or more sub-processes, some of which can be excluded from the system under study. Transport and material handling are examples of processes which can sometimes be partitioned in this way."

"For systems which deliver more than one product or function, or which involve recycle streams, allocation may be avoided or reduced by including further unit processes, hereby expanding the system boundaries so that inputs, outputs or recycles remain within the system."

"2) Where allocation cannot be avoided, the system inputs and outputs should be partitioned between its different products or functions in a way which reflects the underly-

ing physical relationships between them; i.e. they must reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system. These "causal relationships" between flows into and out of the system may be represented by a process model, which can also represent the economic relationship of the system. The resulting allocation will not necessarily be in proportion to any simple measured factor such as the mass or molar flows of co-products."

"3) Where a physical relationship cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way which reflects the economical relationships between them. For example, burdens might be allocated between co-products in proportion to the economic value of the products."

"Any deviation from these procedures shall be documented and justified."

6 Outlook

The standardisation outline found in ISO CD 14041 represents the present basis for the developmental state of LCA. This development is still far from complete. Initiatives taken by SETAC or the EU committee (see LCANET) are involved in this process.

The standardisation procedure cannot be considered as a completed entity, but must routinely undergo further revisions which take the continuing developments into consideration.

Note Added in Proof

Current State of ISO 14041 (March 1997)

Iso 14041 has now left the state of a committee draft and is considered as a DIS (Draft of International Standard)

Life Cycle Interpretation – A Brand New Perspective?

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1 Introduction

Life Cycle Interpretation – a new star on the LCA sky is born! According to ISO 14040, Life Cycle Interpretation is the last formal step in the whole LCA procedure. However, we are all familiar with the iterative nature of LCA as such. So, what does this step contain? One thing is for sure: It is not the former Improvement Assessment as it was suggested by SETAC.

The discussion about the Interpretation step shows the real character of the 14040 series development. It is not alone the standardization of current practice in order to guide users and help interested parties to draw a correct figure of an LCA. It is a process in parallel to the scientific development of LCA and the requests arising from the use of this tool in practice. Standardization of LCA is a struggle for consensus in a methodological development procedure. Nevertheless, the question remains: What does it mean?

2 Aim of Life Cycle Interpretation

Life Cycle Interpretation is a part of the LCA methodology which was introduced, driven from the needs of the users before the background of the problem of how to handle the findings from today's LCAs. Questions like, "What does this difference mean?", "How reliable are these results?" or "Are the findings made in accordance with Goal and Scope?" are constantly being raised – and the LCA framework has offered no solution to the problem.

The interpretation step was invented to provide answers to these questions – an invention which in the light of the day should be quite familiar to all scientists and individuals who are familiar with good scientific practice.

Life Cycle Interpretation is a step before the conclusions are drawn, the step before the decision making process is being fed with the findings in a study. The real aim of this step is to provide reliability and a meaning to the LCA

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